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L7: Entry 14 of 15 File: USPT Apr 11, 1995

DOCUMENT-IDENTIFIER: US 5404661 A
TITLE: Method and apparatus for determining the location of a work implement

Abstract Paragraph Left (1):
An apparatus for determining the location of a work implement at a work site is provided. The apparatus includes an undercarriage, a car body rotatably connected to the undercarriage, a boom connected to the car body, a stick connected to the boom, a work implement connected to the stick, and a positioning system including a receiver connected to the stick and a processor for determining the location of the receiver in three dimensional space at a plurality of points as the car body is rotated and for determining the location and orientation of the work implement.

Brief Summary Paragraph Right (1):
The invention relates generally to control of work machines, and more particularly, to a method and apparatus for determining the location and orientation of a work implement in response to an external reference.

Brief Summary Paragraph Right (2):
Work machines such as mining shovels and the like are used for excavation work. These excavating machines have work implements which consist of a boom, a stick and a bucket. The stick and bucket are controlably actuated by a set of cables and gear drives. In the drawing shown in FIG. 1, a mining shovel 102 is shown in which the boom 104 remains in a substantially fixed position with respect to the car body 106, the bucket 108 is fixed to the stick 110, and the stick 110 is movable with respect to the boom 104 in response to hoist cables 112 and a gear drive included in a yoke 114. An operator typically manipulates the work implement to perform a sequence of distinct functions which constitute a complete excavation work cycle.

Brief Summary Paragraph Right (3):
Prior art monitoring and control systems for linkage type machines require multiple sensors to determine the orientation and configuration of the implement linkage or bucket. Linkage sensors such as yo-yo devices and rotary sensors mounted on linkage members moving relative to each other, in general, have not proved to have long life. Also, if not only linkage orientation and configuration with respect to the work machine is required but also position and orientation of the work machine itself within the work site, then separate sensors and systems are required to provide the additional information.

Brief Summary Paragraph Right (8):
In one aspect of the invention, an apparatus for determining the location of a work implement at a work site is provided. The apparatus includes an undercarriage, a car body rotatably connected to the undercarriage, a boom connected to the car body, a stick connected to the boom, a work implement connected to the stick, and a positioning system including a receiver connected to the stick and a processor for determining the location of the receiver in three dimensional space at a plurality of points as the car body is rotated and for determining the location and orientation of the work implement.

Brief Summary Paragraph Right (9):
In a second aspect of the invention, a method is provided for determining the location of a mining shovel at a work site, the mining shovel including an undercarriage, a car body rotatably connected to the undercarriage, a boom connected to the car body, a

stick connected to the boom, and a work implement connected to the stick. The method includes the steps of rotating the car body, receiving signals from an external reference source, determining the position of a point on the stick in response to the received signals, determining the location of the point on the stick in three dimensional space at a plurality of points as said car body is rotated, and determining the location and orientation of the work implement in response to the location of the plurality of points.

Detailed Description Paragraph Right (2):
The receiver 202 is advantageously connected to the stick 110 such that the antenna orientation does not change as the stick pivots with respect to the boom. Without such compensation for changes in orientation of the stick, the field of view of the receiver 202 would change as the stick 110 pivots about the boom 104 so that at some stick positions, the receiver 202 would be unable to receive signals from satellites in some portions of the sky.

Detailed Description Paragraph Right (3):
In the preferred embodiment, the receiver mounting is a pendulum type mounting including a pivot with the receiver 202 being elevationally above the pivot and a heavy weight (not shown) located elevationally below the pivot. The weight and pivot maintain the receiver 202 in substantially the same orientation even though the stick to which it is mounted pivots about the boom 104. A small portion of the sky is still obscured if the car body 106 is canted from the horizontal in the transverse direction. However, in most operations this effect is insignificant. To correct any error caused by this effect, a more complex arrangement is included, such as a bracket extending from the stick with a ballsocket arrangement having the receiver 202 connected to the ball above the socket and the heavy weight connected to the ball below the socket. In this way, the weight prevents the orientation of the receiver 202 from being changed along any axis when the machine is within most normal ranges of operation. Other, more complex arrangments to maintain the orientation of the receiver 202 are also suitable for use in connection with the invention without deviating from its scope.

Detailed Description Paragraph Right (9):
Turning now to FIG. 6, the method of the present invention is shown schematically. Using a known three-dimensional positioning system with an external reference, for example (but not limited to) 3-D laser, GPS, GPS/laser combinations, radio triangulation, microwave, or radar, receiver 202 position coordinates are determined in block 602 as the machine operates within the work site. These coordinates are instantaneously supplied as a series of discrete points to a differencing algorithm at 604. The differencing algorithm calculates the receiver position and path in real time. Digitized models of the actual and desired site geographies are loaded or stored at block 606, an accessible digital storage and retrieval facility, for example a local digital computer. The differencing algorithm 604 retrieves, manipulates and updates the site models from 606 and generates at 608 a dynamic site database of the difference between the actual site and the desired site model, updating the actual site model in real-time as new position information is received from block 602. This dynamically updated site model is then made available to the operator in display step 610, providing real time position and site geography/topography updates in human readable form. Using the information from the display the operator can efficiently monitor and direct the manual control of the machine at 612.

Detailed Description Paragraph Right (10):
Additionally, or alternately, the dynamic update information can be provided to an automatic machine control system at 614. The controls can provide an operator assist to minimize machine work and limit the manual controls if the operator's proposed action would, for example, overload the machine. Alternately, the site update information from the dynamic database can be used to provide fully automatic machine/tool control.

Detailed Description Paragraph Right (11):
Referring now to FIG. 7, an apparatus which can be used in connection with the receipt and processing of GPS signals to carry out the present invention is shown in block diagram form comprising a GPS receiver apparatus 702 with a local reference antenna and a satellite antenna; a digital processor 704 employing a differencing algorithm,

and connected to receive position signals from 702; a digital storage and retrieval facility 706 accessed and updated by processor 704, and an operator display and/or automatic machine controls at 708 receiving signals from processor 704.

Detailed Description Paragraph Right (12):
GPS receiver system 702 includes a satellite antenna receiving signals from global positioning satellites, and a local reference antenna. The GPS receiver system 702 uses position signals from the satellite antenna and differential correction signals from the local reference antenna to generate position coordinate data in three-dimensions to centimeter accuracy for moving objects. Alternatively, raw data from the reference antenna can be processed by the system to determine the coordinate data.

Detailed Description Paragraph Right (13):
This position information is supplied to digital processor 704 on a real-time basis as the coordinate sampling rate of the GPS receiver 702 permits. The digital storage facility 706 stores a first site model of the desired excavation, for example according to a mining engineer's plan, and a second digitized site model of the actual site geography, for example as initially surveyed. The site model corresponding to the actual site geography can be accessed and updated in real time by digital processor 704 as it receives new position information from GPS receiver 702.

Detailed Description Paragraph Right (15):
Referring now to FIG. 8, a more detailed schematic of a system according to FIG. 7 is shown using kinematic GPS for position reference signals. A base reference module 802 and a position module 804 together determine the three-dimensional coordinates of the receiver 202 relative to the site, while an update/control module 806 converts this position information into real time representations of the machine, bucket, and work site which can be used to accurately monitor and control the machine.

Detailed Description Paragraph Right (16):
Base reference module 802 includes a stationary GPS receiver 808; a computer 810 receiving input from receiver 808; reference receiver GPS software 812, temporarily or permanently stored in the computer 810; a standard computer monitor screen 814; and a digital transceiver-type radio 816 connected to the computer and capable of transmitting a digital data stream. In the illustrative embodiment base reference receiver 808 is a high accuracy kinematic GPS receiver; computer 810 for example is a 486DX computer with a hard drive, 8 megabyte RAM, two serial communication ports, a printer port, an external monitor port, and an external keyboard port; monitor screen 814 is a passive matrix color LCD or any other suitable display type, such as color VGA; and radio 816 is a commercially available digital data transceiver.

Detailed Description Paragraph Right (17):
Position module 804 comprises a matching kinematic GPS receiver 202, a matching computer 818 receiving input from receiver 202, kinematic GPS software 820 stored permanently or temporarily in computer 818, and a matching transceiver-type digital radio 822 which receives signals from radio 816 in base reference module 802. In the illustrative embodiment position module 804 is located on the mining shovel to move with it over the work site.

Detailed Description Paragraph Right (21):
Base reference station 802 is fixed at a point of known three-dimensional coordinates relative to the work site. Through receiver 808 base reference station 802 receives position information from a GPS satellite constellation, using the reference GPS software 812 to derive an instantaneous error quantity or correction factor in known manner. This correction factor is broadcast from base station 802 to position station 804 on the mobile machine via radio link 816,822. Alternatively, raw position data can be transmitted from base station 802 to position station 804 via radio link 816,822, and processed by computer 818.

Detailed Description Paragraph Right (22):
Machine-mounted receiver 202 receives position information from the satellite constellation, while the kinematic GPS software 820 combines the signal from receiver 202 and the correction factor from base reference 802 to determine the position of receiver 202 relative to base reference 802 and the work site within a few

centimeters. This position information is three-dimensional (e.g., latitude, longitude and elevation) and is available on a point-by-point basis according to the sampling rate of the GPS system.

Detailed Description Paragraph Right (24):
Because the sampling rate of the position module 804 results in a time/distance delay between position coordinate points as the machine operates, the dynamic database 828 of the present invention uses a differencing algorithm to determine and update in real-time the path of the receiver 202.

Detailed Description Paragraph Right (25):
With the knowledge of the bucket's exact position relative to the site, a digitized view of the site, and the machine's progress relative thereto, the operator can maneuver the bucket to excavate material without having to rely on physical markers placed over the surface of the site. And, as the operator operates the machine within the work site the dynamic database 828 continues to read and manipulate incoming position information from module 804 to dynamically update both the machine's position relative to the site and the position and orientation of the bucket.

Detailed Description Paragraph Right (26):
The mining shovel 102 is equipped with a positioning system capable of determining the position of the machine and/or its bucket 108 with a high degree of accuracy, in the preferred embodiment a phase differential GPS receiver 202 located on the machine at fixed, known coordinates relative to the stick 110. Machine-mounted receiver 202 receives position signals from a GPS constellation and an error/correction signal from base reference 808 via radio link 816,822 as described in FIG. 8. Machine-mounted receiver 202 uses both the satellite signals and the error/correction signal from base reference 808 to accurately determine its position in three-dimensional space. Alternatively, raw position data can be transmitted from base reference 808, and processed in known fashion by the machine-mounted receiver system to achieve the same result. Information on kinematic GPS and a system suitable for use with the present invention can be found, for example, in U.S. Pat. No. 4,812,991 dated Mar. 14, 1989 and U.S. Pat. No. 4,963,889 dated Oct. 16, 1990, both to Hatch. Using kinematic GPS or other suitable three-dimensional position signals from an external reference, the location of receiver 202 can be accurately determined on a point-by-point basis within a few centimeters as the mining shovel 102 operates within the work site. The present sampling rate for coordinate points using the illustrative positioning system is approximately one point per second.

Detailed Description Paragraph Right (27):
The coordinates of base receiver 808 can be determined in any known fashion, such as GPS positioning or conventional surveying. Steps are also being taken in this and other countries to place GPS references at fixed, nationally surveyed sites such as airports. If the reference station is within range (currently approximately 20 miles) of such a nationally surveyed site and local GPS receiver, that local receiver can be used as a base reference. Optionally, a portable receiver such as 808, having a tripod-mounted GPS receiver, and a rebroadcast transmitter can be used. The portable receiver 808 is surveyed in place at or near the work site.

Detailed Description Paragraph Right (30):
However the work site is surveyed, and whether the machine operators and their supervisors are working from a paper design or a digitized site plan, the prior practice is to physically stake out the various contours or reference points of the site with marked instructions for the machine operators. Using the stakes and markings for reference, the operators must estimate by sight where and how much to excavate. Periodically during this process the operator's progress is manually checked to coordinate the contouring operations in static, step-by-step fashion until the final contour is achieved. This manual periodic updating and checking is labor-intensive, time consuming, and inherently provides less than ideal results.

Detailed Description Paragraph Right (33):
Referring now to FIG. 9, a system according to the present invention is schematically shown for closed-loop automatic control of one or more machine or tool operating systems. While the embodiment of FIG. 9 is capable of use with or without a supplemental operator display as described above, for purposes of this illustration

only automatic machine controls are shown. A suitable digital processing facility, for example a computer as described in the foregoing embodiments, containing the algorithms of the dynamic database of the invention is shown at 904. The dynamic database 904 receives 3-D instantaneous position information from GPS receiver system 906. The desired digitized site model 908 is loaded or stored in the database of computer 904 in any suitable manner, for example on a suitable disk memory. Automatic machine control module 912 contains machine controls 914 connected to operate, for example, steering, tool and drive systems 916, 918, 920 on the mining shovel 102. Automatic machine controls 914 are capable of receiving signals from the dynamic database in computer 904 representing the difference between the actual site model 910 and the desired site model 908 to operate the steering, tool and drive systems of the machine to bring the actual site model into conformity with the desired site model. As the automatic machine controls 914 operate the various steering, tool and drive systems of the machine, the alterations made to the site and the current position and direction of the machine are received, read and manipulated by the dynamic database at 904 to update the actual site model. The actual site update information is received by database 904, which correspondingly updates the signals delivered to machine controls 914 for operation of the steering, tool and drive systems of the machine as it progresses over the site to bring the actual site model into conformity with the desired site model.

Detailed Description Paragraph Right (34):
Turning now to the illustration of FIG. 10, the calculation of the location and orientation of the car body 106 and the location of the bucket 108 which is performed by the computer 824 is described. As described below, roll and pitch of an excavator refers to the side-side and fore-aft slope. Since a shovel rotates, roll and pitch continually varies from the operator's perspective in many operating environments. Therefore, the equation of the plane upon which the car body 106 rotates is calculated, and from this equation, the slope, or roll and pitch, can be displayed using whatever frame of reference is desired. The two most common frames of reference would be to display the surface using perpendicular axes determined by N-S and E-W, or along and transverse to the machines fore-aft axis.

Detailed Description Paragraph Right (35):
The calculations listed below determine the equation of a plane from the x, y, and z coordinates of 3 points sampled by the receiver 202. For ease of understanding, arbitrary values were selected to provide sample calculations; however, none of the values used should in any way limit the generality of the invention and these formulae.

Detailed Description Paragraph Right (44):
Once the height of antenna rotation above the ground is determined from a look up table or equation which contains basic linkage data (or a fixed distance if the antenna is mounted on the carbody), the intersection of the line of carbody rotation and the ground can be calculated. This point is important because the z coordinate indicates the elevation of the ground directly beneath the machine which can be compared to the desired bench height.

Detailed Description Paragraph Right (49):
Where pt.sub.-- x.sub.-- gnd.sub.-- rot.sub.-- center, pt.sub.-- y.sub.-- gnd.sub.-- rot.sub.-- center, and pt.sub.-- z.sub.-- gnd.sub.-- rot.sub.-- center are the coordinates in x, y, and z, respectively, of the intersection of the axis of rotation with the ground.

Detailed Description Paragraph Right (50):
Now, enough information is known to display the shovel location and linkage position relative to the surroundings. With a known location and orientation of the shovel, each point of the receiver 202 defines a unique location of the bucket 108. As the shovel works and rotates, the angular rotation can also be calculated and displayed.

Detailed Description Paragraph Right (51):
At first, it would seem that since the line of rotation is known and the coordinates of the GPS antenna are continually being sampled, that the plan view could be displayed simply by monitoring the X, y coordinates of the antenna relative to the center of rotation. However, since the present invention is a general system in which

the antenna does not have to be mounted along the linkage axis, it is possible to have identical x,y antenna coordinates for different carbody rotations. This possible outcome is illustrated in FIGS. 11a and 11b.

Detailed Description Paragraph Right (55):
A flow chart of an algorithm to be executed by the computer 824 in one embodiment of the invention is illustrated in FIGS. 12a-12i. The GPS reference station 802, the mining shovel 102, and the on-board electronics are powered up at block 1202. The shovel geometry and site data are uploaded to the computer 824 form the data base 828 in blocks 1204 and 1206, respectively. The variables and flags listed in block 1208 are initialized. The GPS position of the receiver 202 is sampled and time stamped at block 1210. The signals from the hoist power sensor 832, crowd power sensor 834, travel current sensor 836, forward/reverse indicator 838, swing current sensor 840, bucket dumped sensor 842, and truck loaded indicator 844 are sampled at blocks 1212-1224, respectively.

Detailed Description Paragraph Right (58):
At block 1238, the operator interface 830 displays the message "swing car body". The operator is instructed that the hoist, crowd, and travel controls are not to be manipulated during swing. When swing.sub.-- current is sensed to exceed zero, receiver 202 locations derived by the kinematic GPS system are stored at regular intervals until the operator indicates via the keypad that rotation sampling is complete at block 1242. The operator interface 830 then indicates the "rotation setup is complete" and the rotation.sub.-- setup flag is set equal to "true". The shovel.sub.-- position.sub.-- count is incremented at block 1246.

Detailed Description Paragraph Right (59):
The plane of rotation of the receiver 202 is calculated in block 1248 as described above in connection with FIG. 10. The computer 824 then calculates at block 1250 a look-up table of the fore-aft pitch and side-side roll of the car body for the 360 degrees of rotation. Alternatively, the North-South inclination and East-West inclination of the car body is displayed on the operator interface 830.

Detailed Description Paragraph Right (60):
At blocks 1252 and 1254, the center of rotation of the plane of receiver rotation and the radius of the arc described by the receiver 202 movement are calculated as described above in connection with FIG. 10. The equation of the line of rotation perpendicular to the plane of the car body 106 is calculated at block 1256 and the distance from the center of rotation of the receiver 202 from the ground is calculated at block 1258. The coordinates of the intersection of the line of rotation with the ground is determined at block 1260. At block 1262, the location of the bucket 108 is determined in response to the location of the receiver 202 and the above calculated values.

Detailed Description Paragraph Right (62):
Alternatively, the position of the work machine is only calculated, and the machine displayed at the work site, in response to the sampled points fitting the definition of a circle. This generally will occur only when the carbody rotates and the undercarriage is stationary.

Detailed Description Paragraph Right (70):
To remedy this problem, in FIGS. 15a-c a subroutine determines the path of the operative portion of the bucket 108 relative to the site plan grid. At step 1502 in FIG. 15a, the module determines whether the machine-mounted receiver position has changed latitudinally or longitudinally (in the x or y directions in an (x, y, z) coordinate system) relative to the site. If yes, the system at step 1504 determines whether this is the first system loop. If the present loop is not the first loop, the machine/bucket path determined and displayed from the previous loops is erased at step 1506 for updating in the present loop. If the present loop is the first loop, step 1506 is simply bypassed, as there is no machine path history to erase.

Detailed Description Paragraph Right (71):
At step 1508 the mining shovel 102 and bucket 108 are initially drawn. If already drawn, the mining shovel 102 and bucket 108 are erased from the previous position on the site model plan at step 1510. At step 1512 the system determines whether the

bucket center's current position coordinates are outside the grid element occupied in the last system loop.

Detailed Description Paragraph Right (74):
At step 1516 the system determines whether the bucket has moved since the last system loop. If the bucket has moved, the system proceeds to step 1518 to determine the real-time path of the bucket over the site plan grid in a manner described in further detail below with reference to FIG. 16. If at step 1516 the bucket has not moved since the last system loop, the system bypasses step 1518. At step 1520 the system uses the above-determined receiver path information to calculate the machine icon position and orientation. At step 1522 this information is used to determine the current or actual site geography and the desired site geography profiles. At step 1524 these images are displayed on the operator interface 830 in either the bench screen or the ore screen. At step 1528 the system next draws the mining shovel and bucket on the operator interface 830 to reflect the most recent machine movement and site alterations in the path of the bucket.

Detailed Description Paragraph Right (77):
The subroutine for step 1518 in FIG. 15c which updates the bucket path and current site plan is shown in further detail in FIGS. 16a-b. While the algorithm of step 1514 compensates for the lack of complete correspondence between the width of the machine or tool and the number of grid elements completely traversed by the machine or tool, the distance and direction changes which the machine/tool makes between GPS position readings results in a loss of real time update information over a portion of the machine's travel. This is particularly acute where implement travel speed is high relative to the grid elements of the site plan. For example, where the grid elements are one meter square and the sampling rate of the position system is one coordinate sample per second, an implement traveling at 18 kilometers per hour travels approximately five meters or five grid squares between position samplings. Accordingly, there is no real time information with respect to at least the intermediate three of the five grid squares covered by the machine.

Detailed Description Paragraph Right (78):
To solve this problem a "fill in the polygon" algorithm is used in step 1518 to estimate the path traversed by the bucket 108 between coordinate samplings. In FIG. 16, the algorithm at step 1518a locates a rectangle on the site plan grid surface defined by the effective ends of the bucket 108 at positions (x.sub.1, y.sub.1) and (x.sub.2, y.sub.2) and coordinate position (x.sub.0, y.sub.0). At steps 1518b, 1518c and 1518f a search algorithm searches within the rectangle's borders for those grid elements within a polygon defined between the two bucket positions; i.e., those grid elements traversed by the bucket between its effective ends.

Detailed Description Paragraph Right (79):
At steps 1518d and 1518e these recently-traversed grid elements are "painted", shaded, marked or otherwise updated to inform the operator that these grid elements have been excavated. In step 1518d the ground elevation or z-axis coordinate of the grid elements is updated at coordinate (x.sub.2, y.sub.2). In step 1518e, the bench screen is updated such that a current elevation greater than the target elevation results in the grid elements being, for example, colored red. A current elevation equal to the target elevation results in the grid elements being, for example, colored yellow. A current elevation less than the target elevation results in the grid elements being, for example, colored blue. On the operator interface 830 the update appears as the just-traversed swath of grid elements behind the bucket, colored or otherwise visually updated.

Detailed Description Paragraph Right (81):
In operation the present invention provides a simple system for determining the location and orientation of the mining shovel 106 and bucket 108. with minimal instrumentation on the shovel. In particular, a single GPS receiver 202 is used to provide all of the relevant shovel and bucket location information. The system also displays the shovel and bucket location in the work site with bench elevation and ore locations also indicated to provide a visual indication of the work to be performed without the need for stakes, flags, or other surface markers. The operator can therefore monitor the bucket location during actual operation relative to any established boundaries such as ore/waste boundaries and/or property boundaries.

Records are also maintained of the material excavated by determining the location of the shovel including the bucket relative to the material. Advantageously, the GPS antenna is located far enough away from the material being loaded into the bucket and far enough away from any moving shovel parts that the antenna will not be subjected to damage.

Detailed Description Paragraph Left (3):
where midpt.sub.-- 1.sub.-- 2.sub. x, midpt.sub.-- 1.sub.-- 2.sub. y, and midpt.sub.-- 1.sub.-- 2.sub.-- z refer to the x, y, and z coordinates, respectively, of the midpoint of the line connecting pt1 and pt 2.

CLAIMS:

1. An apparatus for determining the location of a digging implement at a work site, comprising:

an undercarriage;

a car body rotatably connected to said undercarriage;

a boom connected to said car body;

a stick connected to said boom;

a work implement connected to said stick;

means for rotating said car body; and

a positioning system including a receiver connected to said stick and a processing means for determining the location of said receiver in three dimensional space at a plurality of points as said car body is rotated and for determining the location and orientation of said work implement in response to the location of said plurality of points.

11. An apparatus for determining the location of a digging implement at a work site, comprising:

an undercarriage;

a car body rotatably connected to said undercarriage;

a boom connected to said car body;

a stick connected to said boom;

a work implement connected to said stick;

means for rotating said car body;

a positioning system including a receiver connected to said stick;

an initialization means for determining the location and orientation of said car body when the undercarriage has been moved, said initialization means including a processing means for determining the location of said receiver in three dimensional space at a plurality of points as said car body is rotated and determining the location and orientation of said work implement in response to the location of said plurality of points; and

means for tracking the location of said work implement throughout a work cycle in response to the location of said receiver.

21. A method for determining the location of a mining shovel at a work site, the mining shovel including an undercarriage, a car body rotatably connected to the undercarriage, a boom connected to the car body, a stick connected to the boom, and a work implement connected to the stick, comprising the steps of:

rotating the car body;

receiving signals from an external reference source;

determining the position of a point on the stick in response to the received signals;

determining the location of the point on the stick in three dimensional space at a plurality of points as said car body is rotated; and

determining the location and orientation of the work implement in response to the location of the plurality of points.

27. A method for determining the location of a mining shovel at a work site, the mining shovel including an undercarriage, a car body rotatably connected to the undercarriage, a boom connected to the car body, a stick connected to the boom, and a work implement connected to the stick, comprising the steps of:

rotating the car body;

receiving signals from an external reference source;

determining the position of a point on the stick in response to the received signals;

initializing the determining the location and orientation of the car body after the undercarriage has been moved, said initializing step including the steps of determining the location of said point on the stick in three dimensional space at a plurality of points as said car body is rotated and determining the location and orientation of the work implement in response to the location of the plurality of points; and

tracking the location of the work implement throughout a work cycle in response to the location of the point on the stick.

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L7: Entry 5 of 15 File: USPT Sep 18, 2001

DOCUMENT-IDENTIFIER: US 6292725 B1
TITLE: Interference preventing device for vehicle

Brief Summary Paragraph Right (6):
As a consequence, the above 2) autonomous traveling control system using positional measurement by dead reckoning, inertial navigation and GPS, is adopted in such a working site as a mine. This autonomous traveling control system controls vehicles to travel along predetermined traveling paths while comparing pre-stored position data of the predetermined traveling path with the actually measured positions of the vehicles, with the advantage that it is unnecessary to dispose the guide wires, therefore initial investment is low, and predetermined traveling paths can be freely changed compared with the 1) guide wire (guide marker) control system.

Detailed Description Paragraph Right (23):
A tire rotation sensor 30 (e.g. dial pulse encoder), which is a vehicle traveling distance detection section, is disposed on the tires of the vehicle 10 to detect the rotation speed N of the tires. This tire rotation sensor 30 is disposed for front wheels 30a and for rear wheels 30b respectively. A gyro 31 (e.g. optical fiber gyro), which is a vehicle orientation detection section, is disposed on the body of the vehicle to detect the angular velocity of the orientation angle of the vehicle.

Detailed Description Paragraph Right (24):
The vehicle position (X, Y) (a position on the 2-dimensional coordinate system X-Y) is detected based on the respective output of the above tire rotation sensor 30 and the gyro 31, as described later, but since this vehicle position includes accumulated errors due to tire slippage and other factors, the accumulated errors may be intermittently corrected, for example, by the relative positional relationship between the vehicle and reflection poles, which are disposed intermittently along the predetermined traveling path of the vehicle.

Detailed Description Paragraph Right (25):
The vehicle position may be measured by a GPS (Global Positioning System) rather than measuring the vehicle position based on the output signals of the tire rotation sensor and the output signals of the gyro, as mentioned above. Also, an inertial navigation system or various beacons may be used. It is also possible to measure the position by combining these methods.

Detailed Description Paragraph Right (26):
Arithmetic processing based on the detection signal of the tire rotation sensor 30, which is a vehicle traveling distance detection section, and the detection signal of the gyro 31, which is a vehicle orientation detection section, will be explained next.

Detailed Description Paragraph Right (28):
When a detection signal of the tire rotation sensor 30, which is a vehicle traveling distance detection section, and a detection signal of the gyro 31, which is a vehicle orientation detection section, are input to the position measurement equipment 32, the following processing is sequentially executed.

Detailed Description Paragraph Right (31):
The change of vehicle orientation .DELTA..theta. is calculated by integrating the angular velocity .omega. of the orientation angle of the vehicle based on the

detection signal of the gyro 31, and the current vehicle orientation .theta. from the initial vehicle orientation is calculated by adding the change of the orientation .DELTA..theta. to the known initial orientation.

Detailed Description Paragraph Right (32):
The vehicle coordinate position (X, Y) on an X-Y coordinate is determined by integrating the product of the above vehicle traveling distance S and sine sin and cosine cos of the vehicle orientation .theta., which is S.multidot.sin .theta., S.multidot.cos .theta..

Detailed Description Paragraph Right (34):
The vehicle control equipment 35 compares the locus 41 of the vehicle 10 (current position P), which is computed as above, and the predetermined traveling path 40 (target point position P'), which is a target route, and controls the vehicle 10 based on dead reckoning so that the vehicle 10 traces the predetermined traveling path 40. In other words, the vehicle control equipment 35 outputs predetermined electric signals to the steering hydraulic solenoid proportional control valve and controls the steering angle of the steering so that the sequential target vehicle positions P'1, P'2, P'3 . . . and the target vehicle orientations .theta.'1, .theta.'2, .theta.'3 . . . on the predetermined traveling path 40 are obtained. The vehicle control equipment 35 also outputs predetermined electric signals to the electronic control governor, the transmission solenoid valve, and to the brake pressure solenoid proportional control valve so that the sequential target vehicle positions and the target vehicle orientations on the predetermined traveling path 40 are obtained, and controls the rotation speed of the engine, velocity steps of the transmission and the brake pressure. In this way, the vehicle 10 is guided so as to travel along the predetermined traveling path 40. This is the same for the other vehicles 11, 12, ...

Detailed Description Paragraph Right (40):
The data on the predetermined traveling path of each vehicle is stored in the course data storage equipment 33 of each vehicle by teaching. Then the monitoring station 20 transmits the instruction data to instruct the final target point (destination) to each vehicle 10, . . . via the transmission section 21 of the monitoring station-vehicle communication equipment 23 so as to start a playback operation. If position measurement is performed by GPS, the monitoring station 20 transmits the differential data of GPS to each vehicle.

Detailed Description Paragraph Right (49):
The vehicles judge mutual approach of the vehicle by transmitting/receiving the respective current position data via the inter-vehicle communication between the respective vehicles 10, . . . , but the accuracy of priority and accuracy of avoiding a collision when the vehicles enter a cross-section may be improved by transmitting/receiving the orientation data .theta., velocity data, data on reliability (error) of position measurement, data on the deviation of the vehicle from the predetermined traveling path 40, data on the weight of the vehicle, and data on the distance to a cross-section as well. In the same way, the accuracy of velocity to decelerate and the accuracy of avoiding a collision when the vehicles pass each other may be improved by transmitting/receiving the orientation data .theta., velocity data, data on the reliability (error) of position measurement, data on the deviation of the vehicle from the predetermined traveling path 40, data on the weight of the vehicle, and data on the effective detection distance of the obstacle detection sensor, as well as the position data.

Detailed Description Paragraph Right (51):
Here the data on the predetermined traveling path 40 is data on the sequence of points indicating each spot P1, P2, P3 . . . on the predetermined path 40, and each spot P1, P2, P3 . . . has such information as two dimensional coordinate positions (X, Y) when a predetermined point in the working site is regarded as an origin, sight distance, and the velocity of the vehicle. The spots P1, P2, P3 . . . are divided at an interval required to pass each spot, one second for example, and therefore each spot P1, P2, P3 . . . and the estimated time to pass the spot t correspond to each other at a 1 to 1 ratio.

Detailed Description Paragraph Right (105):

The position measurement section 72 is for measuring the current traveling position of the unmanned vehicle 10 using GPS (Global Positioning System), a tire rotation speed sensor for obtaining traveling distance information, and an optical fiber gyro for obtaining traveling direction information.

Detailed Description Paragraph Right (123):
The above mentioned manned vehicle is, for example, a grader for road repair, a work vehicle for transporting workers and fuel, or a monitoring vehicle for monitoring unmanned vehicle. The manned vehicle does not have an automatic steering apparatus, but has a control system corresponding to the control system shown in FIG. 11. The manned vehicle, of course, transmits a flag denoting that the vehicle is a manned vehicle.

Detailed Description Paragraph Right (142):
The inclination of the course where the vehicle is traveling may be added to the parameters of the function fv to determine the above velocity v pass so that when the inclination of the course is great, the traveling velocity v pass of the vehicle climbing a hill is decreased less.

Detailed Description Paragraph Right (144):
The inclination of a slope may be detected by the inclinometer provided to each vehicle, or may be determined by calculation based on the change of course data in the height direction. For the inclinometer, a general sensor for measuring inclination of the vehicle by the direction of gravity can be used.

Detailed Description Paragraph Center (3):
Operation of Vehicle Orientation .theta.

CLAIMS:

32. The vehicle interference prevention system according to claim 20, characterized in that the quantity of state is an inclination of the traveling course of the vehicle.

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L7: Entry 4 of 15 File: USPT Oct 16, 2001

DOCUMENT-IDENTIFIER: US 6304210 B1
TITLE: Location and generation of high accuracy survey control marks using satellites

Assignee Name (1):
Trimble Navigation Limited

Assignee Name (Derived) (1):
Trimble Navigation Limited

Brief Summary Paragraph Right (6):
A guidance system for an earth-working vehicle, such as a tractor, is disclosed in U.S. Pat. No. 4,244,123, issued to Lazure et al. A signal transmitter, such as a rotating laser beam source, is positioned in a field to be worked, and two signal receivers are positioned at fixed, spaced apart, longitudinal locations on the vehicle, to distinguish changes by the vehicle in two horizontal directions. The receivers determine and report on the present location and bearing of the vehicle, based on what may be a phase difference of the signals received at the two receivers.

Brief Summary Paragraph Right (11):
Use of a rotating laser beam for two-dimensional navigation of a land vehicle in a specified region is also disclosed by Boultinghouse et al in U.S. Pat. No. 4,796,198. Three or more reflectors, one having a distinctive reflectivity, are positioned near the boundary of the region to reflect the laser beam back to the vehicle, where the reflected beams are received by a photoelectric cell and generate signals with associated beam arrival directions that allow determination of the present location of the vehicle. Distinctive reflection from the one mirror provides an indication of the angular position of the laser beam on each rotation.

Brief Summary Paragraph Right (12):
U.S. Pat. No. 4,807,131, issued to Clegg, discloses an automated land grading system in which the position of a cutting blade is controlled automatically to provide controlled shaping of a land region being graded. A laser beam is projected in a predetermined pattern across the land region, and a laser detector carried on the grading machine receives the beam and approximately determines the location of the cutting blade and the blade angle and depth appropriate for grading that location in the land region. Information on the desired blade angle and depth is stored by a microprocessor carried on the grading machine and is compared with the actual blade angle and depth to correct the blade orientation and elevation.

Brief Summary Paragraph Right (13):
Olsen et al disclose survey apparatus for collection and processing of geophysical signals, using a Global Positioning System, a GPS base station and one or more data acquisition vehicles, in U.S. Pat. No. 4,814,711. Each vehicle carries geophysical measuring instruments, a GPS signal receiver and processor to determine present location, a visual display of present location, and radio communication equipment to transmit location information to the base station. The base station periodically polls and determines the present location of each vehicle, with reference to a selected survey course that a vehicle is to follow. The base station transmits commands to each vehicle to keep that vehicle on the selected course. Each vehicle also transmits results of the geophysical data it has measured to the base station for correlation and possible display at the base station. This apparatus requires continual tracking, control and correction of the course of each vehicle relative to the desired course

and requires use of non-portable apparatus (a vehicle and its equipment) to provide the desired location and data measurements. All such measurements are transmitted to, and analyzed by the stationary base station, and the measurements probably are accurate only to within a few meters.

Brief Summary Paragraph Right (14):
U.S. Pat. Nos. 4,870,422 and 5,014,066, issued to Counselman, disclose method and apparatus for measuring the length of a baseline vector between two survey marks on the Earth's surface, using a GPS signal antenna, receiver and processor located at each mark to determine the location of at mark (accurate to within a few meters). The location data are determined using GPS carrier phase measurements at each survey mark and are transmitted to a base station for analysis to determine the baseline vector length between the two marks. This approach requires use of two survey spaced apart survey marks and a base station. Use of GPS signals from five or more GPS satellites and use of a surveying time interval of length .DELTA.t.gtoreq.5000 seconds are required in order to reduce the mark location inaccuracies to a less than a centimeter.

Brief Summary Paragraph Right (15):
Paramythioti et al, in U.S. Pat. No. 4,873,449, disclose method and apparatus for three-dimensional surveying, using triangulation and a laser beam that propagates along the perimeter of a triangle. A rotatable mirror, a component of the scene to be surveyed and a light-sensing camera are located at the three vertices of the triangle, and knowledge of the angles of orientation of the rotatable mirror and the camera allow determination of the location of the component of the scene presently being surveyed. Three spaced apart stations, including one station at the scene to be surveyed, and line-of-sight light beam receipt are required here.

Brief Summary Paragraph Right (16):
Survey apparatus and method for mapping a portion of an ocean bottom are disclosed by Gaer in U.S. Pat. No. 4,924,448. Two ships, each equipped with identical GPS signal antennas, receivers and processors, move along two parallel routes a fixed distance apart on the surface of an ocean. Each ship takes radio soundings of a small region of the ocean bottom directly beneath itself and receives a reflected radio sound from that same region that is originally transmitted by the other ship. The depths of the region directly beneath each ship, as determined by each of the two radio sound waveforms and by the GPS-determined locations of the two ships, are determined and compared for purposes of calibration.

Brief Summary Paragraph Right (17):
In U.S. Pat. No. 4,954,833, issued to Evans et al, a method for determining the location of a selected and fixed target or site, using a combination of GPS signals and the local direction of gravitational force. Geodetic azimuth is determined using GPS signals, and the local gravitational force vector is used to relate this location to an astronomical azimuth, using a fixed coordinate system that is independent of the local coordinate system. The target and a reference site are each provided with a GPS signal antenna, receiver and processor to determine the local geodetic azimuth.

Brief Summary Paragraph Right (18):
A method for waste site characterization using GPS is disclosed by Reeser in U.S. Pat. No. 4,973,970. A GPS base station is established on the site, and a plurality of GPS roving receivers, each combined with a contamination level monitor, is used to determine locations of sites for core sampling. Experimental cores are formed in, and pulled from, the waste and examined for contamination level. The GPS-determined location of the core site is transmitted to the base station for archiving and any further hazardous material analysis.

Brief Summary Paragraph Right (19):
Evans, in U.S. Pat. No. 5,030,957, discloses a method for simultaneously measuring orthometric and geometric heights of a site on the Earth's surface. Two or more leveling rods are held at fixed, spaced apart locations, with a known baseline vector between the rods. Each rod holds a GPS signal antenna, receiver and processor that determines a GPS location for each rod. The geometric height of the GPS antenna (or of the intersection of the rod with the Earth's surface) is determined for each rod, and the geometric height difference is determined, using standard GPS measurements

(accurate to within a few meters). The orthometric height difference for each GPS antenna is determined using the measured GPS location of each rod and an ellipsoid or geoid that approximates the local shape of the Earth's surface.

Brief Summary Paragraph Right (20):
A surveying instrument that uses GPS measurements for determining location of a terrestrial site that is not necessarily within a line-of-sight of the satellites is disclosed in U.S. Pat. No. 5,077,557 issued to Ingensand. The instrument uses a GPS signal antenna, receiver and processor combined with a conventional electro-optical or ultrasonic range finder and a local magnetic field vector sensor, at the surveyor's location. The range finder is used to determine the distance to a selected mark that is provided with a signal reflector to return a signal issued by the range finder to the range finder. The magnetic field vector sensor is apparently used to help determine the surveyor's location and to determine the angle of inclination from the surveyor's location to the selected mark.

Brief Summary Paragraph Right (25):
U.S. Pat. No. 5,144,317, issued to Duddek et al, discloses use of a fixed GPS base station and four or more GPS satellites to monitor progress in an open pit mine, including determination of the location and spatial orientation of selected mining equipment, such as a bucket wheel of a travelling excavator. A second GPS receiver is positioned on the equipment item to help determine orientation and movement of the equipment.

Brief Summary Paragraph Right (26):
A geodetic surveying system using three or more non-collinear GPS base stations and a roving land vehicle carrying a fourth GPS receiver is disclosed by Spradley et al in U.S. Pat. No. 5,155,490. The location of each GPS base station must be initially determined over a long period of time (10-12 hours). The land vehicle also carries a GPS receiver and receives GPS signals from four or more GPS satellites and from each base station. Vehicle location data determined from these signals appear to be post-processed to determine the vehicle's location at some time in the past.

Brief Summary Paragraph Right (28):
The invention is a method that satisfies these requirements with a minimum of hardware (signal reception and processing circuitry), using two or more signal receivers in a Satellite Positioning System (SPS), such as the Global Positioning System (GPS) or the Global Orbiting Navigational System (GLONASS). An SPS position determination method known as differential positioning, one version of which is discussed by Allison in U.S. Pat. No. 5,148,179, incorporated by reference herein, is used to measure relevant distances to, and thus locate, a plurality of survey or construction marks on or near the Earth's surface for which such measurements are required.

Brief Summary Paragraph Right (29):
The method begins by positioning an SPS signal reference antenna and is receiver and radio transmitter at a location whose coordinates are known with sufficient accuracy. The reference receiver may be stationary or may be moving, with location coordinates that are known functions of time t. An SPS signal roving receiver is then moved to one or more pre-selected positions that are spaced apart from the reference receiver, using SPS differential positioning relative to the reference receiver location in real time to guide the roving receiver to the pre-selected position. The pre-selected location may exist in a database contained in the roving receiver, which in turn may be a subset of some larger database maintained by a computer located elsewhere. For each pre-selected location entered in the database, a corresponding physical position may exist on or near the Earth's surface. In this case, the invention allows accurate determination of the location of these physical marks, even if a mark has become obscured or buried. Maintenance of a line of sight from the reference receiver to the roving receiver is not required. Alternatively, the mark locations may be defined by the database, without corresponding physical marks, for example by the construction plans of a new road or building. In this situation, the invention allows location of positions with the specified location coordinates on or near the Earth's surface, such that new physical position marks can be generated. These physical position marks may comprise wooden stakes or pegs or chalk marks of a temporary nature, or more permanent marks such as brass monuments set in concrete.

Brief Summary Paragraph Right (31):
The Global Positioning System (GPS) is part of a satellite-based navigation system developed by the United States Defense Department under its NAVSTAR satellite program. A fully operational GPS includes up to 24 satellites approximately uniformly dispersed around six circular orbits with four satellites each, the orbits being inclined at an angle of 55.degree. relative to the equator and being separated from each other by multiples of 60.degree. longitude. The orbits have radii of 26,560 kilometers and are approximately circular. The orbits are non-geosynchronous, with 0.5 sidereal day (11.967 hours) orbital time intervals, so that the satellites move with time relative to the Earth below. Theoretically, three or more GPS satellites will be visible from most points on the Earth's surface, and visual access to three or more such satellites can be used to determine an observer's position anywhere on the Earth's surface, 24 hours per day. Each satellite carries a cesium and rubidium atomic clock to provide timing information for the signals transmitted by the satellites. Internal clock correction is provided for each satellite clock.

Brief Summary Paragraph Right (32):
Each GPS satellite transmits two spread spectrum, L-band carrier signals: an L1 signal having a frequency f1=1575.42 MHz and an L2 signal having a frequency f2=1227.6 MHz. These two frequencies are integral multiples f1=1500 f0 and f2=1200 f0 of a base frequency f0=1.023 MHz. The L1 signal from each satellite is binary phase shift key (BPSK) modulated by two pseudo-random noise (PRN) codes in phase quadrature, designated as the C/A-code and P-code. The L2 signal from each satellite is BPSK modulated by only the P-code. The nature of these PRN codes is described below.

Brief Summary Paragraph Right (34):
Use of the PRN codes allows use of a plurality of GPS satellite signals for determining an observer's position and for providing navigation information. A signal transmitted by a particular GPS signal is selected by generating and matching, or correlating, the PRN code for that particular satellite. All PRN codes are known and are generated or stored in GPS satellite signal receivers carried by ground observers. A first PRN code for each GPS satellite, sometimes referred to as a precision code or P-code, is a relatively long, fine-grained code having an associated clock or chip rate of 10 f0=10.23 MHz. A second PRN code for each GPS satellite, sometimes referred to as a clear/acquisition code or C/A-code, is intended to facilitate rapid satellite signal acquisition and hand-over to the P-code and is a relatively short, coarser-grained code having a clock or chip rate of f0=1.023 MHz. The C/A-code for any GPS satellite has a length of 1023 chips and thus repeats every millisecond. The full P-code has a length of 259 days, with each satellite transmitting a unique portion of the full P-code. The portion of P-code used for a given GPS satellite has a length of precisely one week (7.000 days) before this code portion repeats. Accepted methods for generating the C/A-code and P-code are set forth in the document GPS Interface Control Document ICD-GPS-200, published by Rockwell International Corporation, Satellite Systems Division, Revision A, Sept, 26, 1984, which is incorporated by reference herein.

Brief Summary Paragraph Right (35):
The GPS satellite bit stream includes navigational information on the ephemeris of the transmitting GPS satellite and an almanac for all GPS satellites, with additional parameters providing corrections for ionospheric signal propagation delays suitable for single frequency receivers and for an offset time between satellite clock time and true GPS time. The navigational information is transmitted at a rate of 50 Baud. A useful discussion of the GPS and techniques for obtaining position information from the satellite signals is found in Guide To GPS Positioning, edited by David Wells, Canadian GPS Associates, 1986.

Brief Summary Paragraph Right (36):
A second configuration for global positioning is the Global Orbiting Navigation Satellite System (GLONASS), placed in orbit by the former Soviet Union and now maintained by the Russian Republic. GLONASS also uses 24 satellites, distributed approximately uniformly in three orbital planes of eight satellites each. Each orbital plane has a nominal inclination of 64.8.degree. relative to the equator, and the three orbital planes are separated from each other by multiples of 120.degree. longitude. The GLONASS circular orbits have smaller radii, about 25,510 kilometers, and a satellite period of revolution of 8/17 of a sidereal day (11.26 hours). A GLONASS

satellite and a GPS satellite will thus complete 17 and 16 revolutions, respectively, around the Earth every 8 days. The GLONASS system uses two carrier signals L1 and L2 with frequencies of f1=(1.602+9k/16) GHz and f2=(1.246+7k/16) GHz, where k (=0, 1, 2, . . ., 23) is the channel or satellite number. These frequencies lie in two bands at 1.597-1.617 GHz (L1) and 1.240-1.260 GHz (L2). The L1 code is modulated by a C/A-code (chip rate=0.511 MHz) and by a P-code (chip rate=5.11 MHz). The L2 code is presently modulated only by the P-code. The GLONASS satellites also transmit navigational data at a rate of 50 Baud. Because the channel frequencies are distinguishable from each other, the P-code is the same, and the C/A-code is the same, for each satellite. The methods for receiving and analyzing the GLONASS signals are similar to the methods used for the GPS signals.

Brief Summary Paragraph Right (37):
Reference to a Satellite Positioning System or SPS herein refers to a Global Positioning System, to a Global Orbiting Navigation System, and to any other compatible satellite-based system that provides information by which an observer's position and the time of observation can be determined, all of which meet the requirements of the present invention.

Brief Summary Paragraph Right (38):
A Satellite Positioning System (SPS), such as the Global Positioning System (GPS) or the Global Orbiting Navigation Satellite System (GLONASS), uses transmission of coded radio signals, with the structure described above, from a plurality of Earth-orbiting satellites. A single passive receiver of such signals is capable of determining receiver absolute position in an Earth-centered, Earth-fixed coordinate reference system utilized by the SPS. A configuration of two or more receivers can be used to accurately determine the relative positions between the receivers or stations. This method, known as differential positioning, is far more accurate than absolute positioning, provided that the distances between these stations are substantially less than the distances from these stations to the satellites, which is the usual case. Differential positioning can be used for survey or construction work in the field, providing location coordinates and distances that are accurate to within a few centimeters.

Brief Summary Paragraph Right (41):
One or more stations is designated as a reference station, and is preferably fixed at a known position (or, less likely, is moving with coordinates that are known functions of time). The locations of one or more other stations, known as the roving receiver stations, which also may be stationary or moving, are calculated relative to the present location of the reference station. The approximate absolute position of the reference station is required. This position, if not previously determined, can be computed using established absolute position determination methods that utilize measurement of PRN code phases.

Brief Summary Paragraph Right (42):
In these applications, it is usual to record satellite measurements within the stations, and then post-process the data at a later time, having first combined the data from both stations. In this approach, the position of the roving receiver cannot be determined in real time as the receiver user moves around. Because of this limitation, systems that post-process the data cannot be used to accurately locate, in real time, an existing physical survey mark of known position on or just below the Earth's surface. In addition, for systems that post-process the data, it is not possible to specify an arbitrary pre-selected location by its coordinates contained in a mapping database and to then generate a new physical mark at the corresponding location on the Earth's surface. Applications using a conventional approach rely on data post-processing and are concerned with the determination of the locations of existing physical marks. In such approaches, a physical mark is first generated and the position of this mark is then accurately determined. It is not possible to first establish an arbitrary mark in a mapping database (without a pre-existing physical mark), and then accurately generate the corresponding physical mark at a later time. The present invention does not suffer from these limitations and allows identification, in real time, of the physical location of a mark, beginning with location coordinates of the mark contained in a database.

Brief Summary Paragraph Right (52):

The present invention provides a method that allows measurement of distances and angles and identification of a location with pre-selected coordinates without clear visibility or line of sight between the reference receiver and roving receiver. This allows the method to be used in situations in which traditional optical surveying instruments cannot be used. The method includes a suitable communication system between the reference and roving receivers that operates without requiring direct radio communication between the two receivers. The apparatus used is sufficiently lightweight and portable to allow a single operator to easily locate pre-selected positions and/or perform distance and angle measurements on the Earth's surface in real time.

Brief Summary Paragraph Right (53):
The invention allows the pre-selected location(s) to be defined in any coordinate reference system, including but not limited to the reference system used by the satellites. An example of a satellite coordinate system is the WGS84 geodetic system. Other coordinate systems include state plane coordinates, and geodetic systems with specific datums. To accommodate these various systems, the roving receiver is capable of performing three or seven parameter datum transformations in real-time.

Detailed Description Paragraph Right (2):
In its simplest form, the apparatus uses only two SPS receivers 13 and 14, as shown in FIG. 1. One of these receivers 14 is designated as the reference receiver, and in many survey applications this receiver is stationary relative to the Earth. However, there is no constraint that the reference receiver 14 be non-moving, if the coordinates of the reference receiver are known functions of time t. The other receiver 13, designated as the roving receiver, is in motion relative to the reference receiver. The apparatus in which the invention is embodied can be expanded to include multiple reference and roving receivers.

Detailed Description Paragraph Right (5):
The bandwidth of the radio link must be sufficient for the data rate of the reference receiver. An example of a radio communication system which meets the requirements of the invention is the TRIMTALK 900 radio modem system manufactured by Trimble Navigation Ltd. These radio modems transmit spread-spectrum signals, using code-division-multiple-access (CDMA) modulation in combination with time-division-multiple-access (TDMA), in a band near 900 MHz. The TDMA allows signal separation between multiple radio modems and radio repeaters, as discussed below. This radio modem system does not require licensing for use within the U.S. A different radio modem may be required for operation outside the U.S. The transmission frequency of the radio modem is not important, provided that sufficient bandwidth is available at the chosen frequency. Likewise, the modulation scheme is not important. Other types of radio modems using different modulation schemes and different transmit frequencies can also be used. An independent satellite communication link could also be used place of the radio modems.

Detailed Description Paragraph Right (12):
The roving receiver 13 is connected to an SPS antenna 35 that is attached to an antenna mount such as a range-pole 37, shown in more detail in FIG. 2. The range-pole 37 is used to locate the pre-selected survey location or other desired location. Preferably, the range-pole 37 has a bubble level or similar instrument 39 to indicate the local vertical direction, for proper vertical orientation of the range-pole. Optionally, the range-pole 37 may have a compass or other direction-indicating instrument 41, to indicate the angular displacement from a magnetic north or true north direction of a horizontal line that passes through the intersection of the range-pole with the Earth's surface. A handheld survey controller 45 is also attached to the roving receiver 13. A handheld computer that meets the requirements of the invention is the TDC (Trimble Data Collector) Survey Controller manufactured by Trimble Navigation Ltd. This incorporates an 8.times.20 character graphical display, is sufficiently light-weight, and is connected to the roving receiver via a single cable. This cable provides electrical power and a data communication path. Alternative handheld computers include use of pen-based computers, which are becoming popular. The TDC contains a database of pre-selected locations to which the roving receiver must be moved. This database may be loaded prior to conducting the survey, or may be updated in real-time via the reference/roving receiver TRIMTALK 900 radio link discussed above.

Detailed Description Paragraph Right (13):
The controller 45 optionally incorporates a graphical display 51 that is used to guide the user to the required survey location. The height of the roving receiver antenna 35 above the ground (i.e. the height of the range-pole 37) is recorded and is entered into the controller 45. Using the invention, one person can locate a new mark position, defined by locations coordinates that are pre-selected, or perform distance measurements for an existing mark, using the differential position for the roving receiver 13 determined relative to the known location of the reference receiver 14.

Detailed Description Paragraph Right (15):
The pre-selected survey/construction locations may be defined in any coordinate system. The GPS satellite system uses the WGS84 geodetic coordination reference system. However, most survey applications use different coordinate systems such as local state plane coordinates, transverse Mercators, Lamberts Conformal, or geodetic reference systems based on the NAD83 or NAD27 reference datum. The pre-selected locations to which the roving receiver must be moved may be specified in any of these coordinate systems or others. Therefore, it is necessary to compute 3-parameter or 7-parameter coordinate transformations in real-time by the TDC survey controller, such that the roving receiver can be moved to a position specified in any coordinate system, although the initial roving receiver position may be calculated using the satellite based WGS84 reference system.

Detailed Description Paragraph Right (16):
The reference and roving receivers receive and process L1 and/or L2 signals from SPS signals, such as GPS or GLONASS signals, which allow accurate determination of the relative positions of one or more roving receivers and a reference receiver in real-time. These relative positions, also known as differential positions, baseline vectors, or baselines, can be expressed as vector components in an Earth-centered, Earth-fixed coordinate system, or can be translated into other coordinate systems.

Detailed Description Paragraph Right (18):
Whether the method uses only measurements of the L1 carrier phase, or only measurements of the L2 carrier phase, or a linear combination of both L1 and L2 carrier phase, these measurements can be provided by receivers using a channel configuration as described in A Geodetic Survey Receiver with up to 12 L1 C/A-Code Channels, and 12 L2 Pseudo-P-Code Channels, presented by M. T. Allison, D. Farmer, G. Lennen, and K. Martin at the Third International Technical Meeting of the Satellite Division of the Institute of Navigation, Colorado Springs, Colo., September 1990. Alternatively, receivers can be used that have independent L2 P-code channels for each of the received satellite signals, or that have independent L1 P-code channels for each of the received satellite signals. An example of such a receiver is the Model 4000SSE Geodetic Survey Receiver manufactured by Trimble Navigation Ltd, Sunnyvale, Calif., released in July 1992.

Detailed Description Paragraph Right (29):
An alternative option is to incorporate an azimuth measuring device into the range-pole or TDC (which is in turn attached to the range-pole). A suitable device is a flux-gate compass, which can electronically measure azimuth from magnetic north, and input this information to the TDC. The TDC can then compute and display the required direction of the destination relative to the current orientation of the range-pole (incorporating the azimuth device) even when the range-pole and roving receiver SPS antenna are stationary.

Other Reference Publication (1):
Wells et al, "Guide to GPS Positioning", Chapter 1, 2nd Printing, May 1987.

CLAIMS:

1. A system for locating a target point having known coordinates, comprising:

a reference position determining device at a known position, said device having means for wireless transmission of measurement data representative of at least said known position and the known coordinates of said target point; and

a roving position determining device responsive to said measurement data, said known coordinates of said target point, and satellite navigation signals and movable to the target point, said roving position determining device having a processor responsive to said measurement data and said satellite navigation signals to determine the position of said roving position determining device relative to said reference position determining device, said roving position determining device being adapted to determine and to reveal its position relative to the target point in response to its determined position and said known coordinates of said target point.

2. A system for locating a target point having known coordinates, comprising:

a reference position determining device at a known position, said reference device having means for wireless transmission of measurement data derived from satellite navigation signals; and

a roving position determining device movable to the target point and having a processor responsive to the measurement data, the satellite navigation signals, the known position of said reference device, and the known coordinates of the target point, the processor being adapted to determine and to reveal the position of said roving device relative to the target point.

3. A system according to claim 2 wherein the measurement data are derived from carrier phase measurements of the satellite navigation signals and the processor is responsive to carrier phase measurements of the satellite navigation signals.

5. A system according to claim 2 wherein the target point is not previously staked out, the known coordinates of the target point are recorded in a data base, the measurement data are derived from carrier phase measurements of the satellite navigation signals, and the processor is responsive to carrier phase measurements of the satellite navigation signals and is adapted to determine and to reveal the position of the roving device relative to the target point with an error of less than 3 centimeters.

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L7: Entry 7 of 15 File: USPT Jun 6, 2000

DOCUMENT-IDENTIFIER: US 6073070 A
TITLE: Agricultural vehicle with treatment device which is adjustable in its position and/or orientation relative to the vehicle

Abstract Paragraph Left (1):
An agricultural vehicle has a main vehicle, a treatment device arranged adjustably relative to the vehicle with respect to at least one of a position and an orientation of the treatment device, a satellite navigation receiving unit, and an evaluating unit which determines from data of the satellite navigation receiving unit an absolute position of at least one reference point on the treatment device in a terrestrial reference system.

Brief Summary Paragraph Right (1):
The present invention relates to an agricultural vehicle with a treatment device which is adjustable relative to the vehicle in its position and orientation, wherein the agricultural vehicle is provided with a GPS satellite navigation receiving unit.

Brief Summary Paragraph Right (2):
Agricultural vehicles such as harvesters, tractors, etc as a rule are provided with a treatment device which is movable and/or adjustable to achieve a spacial position and orientation. Such treatment devices are for example a cutting bar of a harvester, a plough of a tractor, and a device for applying fertilizers or plant protective agents. The position and orientation of the treatment device relative to the vehicle are influenced by manual control by a vehicle driver or by an automatic regulation with sensors for determination of the position and orientation. The control of the position and orientation of the treatment device can be both active so as to operate by controlling of adjusting drives (for example a front loader on a tractor), and also passive by controlling of the vehicle (for example a vehicle trailer).

Brief Summary Paragraph Right (3):
Other agricultural vehicles are known, in which, in addition to the position and orientation of the treatment device relative to the vehicle, also the position and orientation of the treatment device relative to the ground surface is changeable. For example in a combined harvester, a device and a method are known in accordance with which the cutting height or in other words the height of the cutter bar over the ground surface can be adjusted and regulated. With the adjustment and regulation of the position and orientation of the treatment vehicle, frequently nominal and limiting values for the parameter which describe the position and orientation are provided. Thus, nominal values for the cutting height of a combined harvester in dependence on the harvested product are known. A lower limiting value for the cutting height is determined so as to prevent damages to the cutter bar. An upper limiting value is determined by the growth height of the harvested product.

Brief Summary Paragraph Right (4):
The position and orientation of the treatment device relative to the vehicle and relative to the ground are dependent on one another. The dependency is determined by the properties of the ground and therefore generally is known only insufficiently. For the operation of the agricultural vehicle is the position and orientation of the treatment device relative to the ground is however important. Methods are known, in accordance with which the position and orientation of the treatment device relative to the ground are measured, and the position and orientation relative to the vehicle is regulated by adjustments. This is provided for the operation of a combine harvester,

for example by an AUTO-CONTOUR method of the applicant. In many cases, however, the vehicle driver compensates the changed ground property by a manual control.

Brief Summary Paragraph Right (5):
Furthermore, from the German patent document DE 44 31 824 C1 a method is known, which connects the operational data of a combine harvester with the corresponding space coordinate determined in a historic data cadastre and provides from it nominal or limiting operational values for a new treatment. The space coordinates are determined in the prior art by means of a satellite navigation system on the vehicle.

Brief Summary Paragraph Right (6):
Furthermore, the German patent document DE 195 44 112.5 discloses a method for generation of three-dimensional digital terrain models with a vehicle having a satellite navigation system. For the generation of digital terrain models and the generation of data cadastres in the known method the position of a point on the vehicle is considered to be as the basis. For the operation of the vehicle however the position and the orientation of the treatment device is decisive. The accuracy of the produced terrain model is therefore not better than the dimensions of the vehicle permit. This can lead, especially for large machines with broadly arranged treatment devices, to inaccuracies in the terrain model or in data cadastre. The high accuracy of the currently available satellite navigation systems is not completely used in this method. When it is necessary in addition to use the operation data cadaster for regulation of the position and orientation of the treatment device, then the uncertainties in the position of the treatment device make necessary the control and eventually the engagement of the vehicle driver. Since the above mentioned uncertainties first of all occur on uneven terrain, in which the concentration of the vehicle driver must be increased anyway, this can lead to the fact that the efficiency of the agricultural vehicle is not fully utilized or operational disturbances are caused.

Brief Summary Paragraph Right (7):
Accordingly, it is an object of the present invention to provide an agricultural vehicle with a treatment device arranged adjustably relative to a vehicle as to its position and/or orientation, with which an optimization of the operation of an agricultural vehicle is possible, by providing adjustment of an absolute position of a reference point of the treatment device which is movable relative to the vehicle.

Brief Summary Paragraph Right (8):
In keeping with these objects and with others which will become apparent hereinafter, one feature of present invention resides briefly stated, in an agriculture vehicle provided with an evaluating unit which, from the data of a satellite navigation receiving unit, determines an absolute

Brief Summary Paragraph Right (10):
The determination of the absolute position is performed by a known computing algorithm which processes the transducer data from a GPS satellite. In order to provide a sufficient accuracy for the determination of the absolute position, a person skilled in the art can use means which are known from the prior art to reduce the error of the GPS position data. Additional vehicles sensors are used, which for example measure a yawing angle, a wheel rotary speed or a speed over ground, for the evaluation of reference signals which are transmitted from other radio stations.

Brief Summary Paragraph Right (11):
With the present invention it is possible to control the treatment vehicle in accordance with the determined values actually exclusively from the determined position data in connection with a historic data cadastre and/or further machine-mounted sensors, or to distribute the determined position data in a determined position for controlling later treatments with the same or other agricultural vehicles with controllable treatment devices based on historic data cadastre.

Brief Summary Paragraph Right (12):
In accordance with the present invention the agricultural vehicle has an evaluating unit which determines, from the data of the stabilized navigation receiving unit (GPS) the absolute position (Pb1, Pb2 . . .) of at least one reference point (b1, b2, . . .) on the treatment device in a terrestrial reference system. This makes possible in

the known method for determination of operational data cadastres and terrain models, to replace the position of the vehicle by the exact position of the reference point on the treatment device and therefore to provide a higher position of the above mentioned method for an agricultural vehicle with a treatment device adjustable as to its position and the orientation. If the satellite navigation receiving unit is positioned in another point of an agricultural vehicle than the reference point (b1, b2, . . .), the computing algorithm must take into consideration a coordinate transformation which corresponds to another position of the reference point (b1, b2, . . .).

Brief Summary Paragraph Right (13):
In accordance with a preferable embodiment of the present invention, a sequence of positions of at least one point on the treatment device, which during the traveling of the agricultural machine is obtained over the strip, is used as a basic position to produce a precise terrain model. During a new utilization of the agricultural vehicle on the same strip, the operational data stored in the historic data cadastre can be again used. The stored operational data than determined partially or completely the regulation of the position and orientation of the treatment device. In this way the operation of the agricultural vehicle is optimized and simultaneously the driver is unloaded.

Brief Summary Paragraph Right (14):
In accordance with a preferable embodiment of the present invention, characteristic reference lines for the operation of the treatment device are utilized. They are used for improving the terrain profile, so that the drops or raises of the terrain and/or the inclination of the terrain transversely to the traveling direction are determined from the ~~orientation of the above-mentioned~~ reference lines. In accordance with the present invention such a reference line (L1) is provided by the absolute position (Pb1) of the reference point (b1) and a further point or a vector. In accordance with a preferable embodiment of the invention, the speed vector (Vb1) of the reference point (b1) is utilized for determination of the reference line (L1). The speed vector can be taken either directly from the GPS data or a separate speed sensor with a directional sensor, or from two timely following positions of the reference point. In the case of a permanent ground distance (d1) of the reference point (b1) the angle of the reference line (L1) with the horizontal plane (xy) shows the drop or the raise of the ground in a traveling direction.

Brief Summary Paragraph Right (16):
Depending on the plot rate and speed of the agricultural vehicle, the movement vector of the limiting points can be determined also exclusively with computation of the position data, for example when each position of the vehicle is determinable at distances of less than 20 meter of the covered traveling stroke, or the assistance and computation of further sensor data are used when the plot rate goes beyond the above mentioned distance. The selection of the average distance is naturally dependent on the magnitude of the desired accuracy of the movement vectors and the requirements for the performed agricultural works in objective and economical way. The reference lines (L1) can be processed as a steering signal in a regulating electronic system of an automatic steering device. As a directional vector, the reference line (L1) can be drawn for example from a limiting point or a reference point from a nominal travel track or a treatment edge along the same. The regulating electronic system of the automatic steering device compares than the actual position value of the limiting reference point with the nominal position values along the reference line (L1) and provides, with a fixed deviation, and adjusting signal to the steering device which is suitable during a further forward travel to reduce the difference between the nominal position values and actual position values along the reference line L1.

Brief Summary Paragraph Right (18):
In accordance with the present invention, the height over the ground of points over the reference line must be known or determinable. The height is known for example when the ground distance is fixed by a non spring-biased chassis or by a known control circuit (for example by means of ground pressure sensors). Moreover, means a sensors are known which determine the height of the treatment devices over the ground. Such means are for example mechanical distance measuring devices or sonic altimeters. A preferable embodiment of the invention provides such means for determination of the ground distance for at least two points of the reference line L2. These means permit, during tilting of the treatment device relative to the ground, to perform an accurate

determination of the transverse inclination of the ground surface.

Brief Summary Paragraph Right (20):
The invention is described as usable for agricultural vehicles. However, it is believed to be clear for a person skilled in the art that it can be used also in other vehicles, such as for example construction machines which treat and redesign a ground contour with their adjustable working tools. For realization of the inventive idea in another vehicle a person skilled in the art will experience no difficulties to provide corresponding adjustments.

Detailed Description Paragraph Right (1):
FIG. 1 shows a combined harvester as an example of an agricultural vehicle (LNF) from one side. The longitudinal axis of the vehicle and the working device have in this case the same orientation. However, the cutter bar B is adjustable vertically relative to the main vehicle F. The horizontal plane of a terrestrial coordinate system is identified with the line (xy). The ground surface is inclined relative to the line (xy) under a reference point (b1) of the treatment device at an angle of inclination (W1). It can be completely different from the inclination of the ground surface under the vehicle. This leads to the situation that the speed vector (vf1) of reference point Pf1 on the vehicle with an unchanged adjustment of the height can have another orientation than the speed vector (vb1) of the reference point (b1) on the treatment device. If the distance D of the reference point (b1) to the ground surface during the positioning changes (Pb1, Pb1') remains the same, then the angle between the speed vector (vb1) and the horizontal plane (xy) corresponds to the inclination angle (W1) of the ground surface under the reference point (b1). The reference line (L1) is determined here by the absolute position (Pb1) of the reference point (b1) and the speed vector (vb1), which is also determined by the reference point (Pb1'). The value of the reference line (L1) can be used then as a control basis for controlling the treatment device B or as a characteristic value for the ground contour for depositing in the historic data cadaster.

Detailed Description Paragraph Right (2):
A height sensor (HS) and a transverse inclination sensor (QNS) are identified schematically. With these sensors, the relative height position and transverse inclination of the treatment device B to the vehicle F on which it is mounted, can be determined. Also a ground distance sensor (AS1) is identified only schematically, and it can determine the distance to the reference point from the ground. A GPS antenna is schematically shown on the roof of the combine harvester F associated with the point (Pf1). With the evaluation unit (AWE) the absolute position of the point (Pf1) determined by the satellite navigation is transformed on the treatment device B as shown from the illustration of FIG. 6.

Detailed Description Paragraph Right (3):
FIG. 2 shows a front view of the combine harvester. It illustrates a tilting of the treatment device relative to the combine harvester and relative to the ground surface and the associated parameters. The horizontal plane of the terrestrial coordinate system is again identified with the line (xy). The ground surface under the treatment device is inclined in the middle at an angle (Wq). ~~This inclination can be completely~~ different from the inclination of the ground surface under the vehicle, which here is ~~identified by a tilting of the vehicle in another direction~~. The reference line (L2) ~~is provided as a connecting~~ line of two reference points (b1, b2) on the treatment device. The distance sensors (AS1, AS2) determine the distance (da1, da2) of two points of the treatment device (a1, a2) from the ground surface. From the geometrical conditions, the distances (d1, d2) of the reference points (b1, b2) from the ground surface are calculated. The distance of the reference points from the ground surface in the ideal case is identical to the sum of the minimal distance (d0) of the reference points (b1, b2) from the ground surface, or in other words the distance of the reference point when the cutter bar lies on the ground, and the preset ground distance or cutting height (da(x)) are identical. The same distances (d1, d2) of the reference points (b1, b2) provide the angle of reference line (L2) with the horizontal plane (xy) directly with the central inclination angle (Wq) of the ground surface under the treatment unit. In this embodiment of the invention a GPS antenna is located on each reference point (b1, b2). With a difference of the distances (b1, b2) the average inclination angle (Wq) can be calculated from the geometrical conditions.

Detailed Description Paragraph Right (5):
FIG. 4 shows a block diagram of the simplest version of the inventive evaluating unit (AWB). It is provided that the receiver (antenna) of a GPS satellite navigation receiving unit (GPS1) is mounted directly on the reference point (b1) of the treatment device B. In this case the function of the evaluating unit (AWE) is limited to process the data of the GPS receiver, so that the absolute position (Pb1) and optionally the absolute speed (vb1) of the reference point (b1) are indicated on an indicating unit (AGE) stored in a high data cadastre (HDK) and/or supplied to a control device (not shown) for the height/transverse inclination of the cutter bar B. For producing and storing a terrain model (GM) in the data cadastre it suffices in this simplest case to calculate the distance (d1) of the point (b1) from the ground surface from the distance (d0) and the preadjusted cutting height (dSH) by addition and drawn off from the height coordinate from the position (Pb1). The value of (d0) depends on where the reference point on the cutter bar B is arranged, and (d0) can have the value of approximately zero.

Detailed Description Paragraph Right (6):
FIG. 5 shows a block diagram of a preferable embodiment of the inventive evaluating unit. Here the functions of the version of the evaluating unit of FIG. 4 are completed. The evaluating unit determines from the data of the GPS receivers (GPS1, GPS2) the absolute positions (Pb1, Pb2) of the second reference points (b1, b2) and the speed vector (vb1) of a reference point (P1). From this data the reference line (L1) and/or (L2) is generated. In addition, two distance sensors (AS1, AS2) measure the distances of the points (a1, a2) from the ground surface. From the geometrical conditions the evaluating unit interpelates the distances (d1, d2) of the reference points (b1, b2) from the ground surface and the angle (Wq) which the ground surface assumes to the horizontal plane. Further, the evaluating unit determines, from the inclination of the reference line (L1) and two subsequent measurements of the ground distance ~~(d1, d1'), the inclination angle~~ (w1) of the ground surface. From the positions of the points (b1, b2), an improved terrain model is produced, which is stored in the data cadastre for a new treatment of the strip with an available agricultural vehicle.

Detailed Description Paragraph Right (8):
evaluating unit (AWE) also supplies the signal of the transverse inclination sensor (QNS) which provides the relative transverse inclination of the cutting bar of the vehicle F. From this data the evaluating unit (AWE) determines the absolute position of the reference points and/or lines on the treatment device B in a terrestrial reference system. With the assistance of the ground distance sensors (AS1, AS2) arranged on the treatment device B the connection to the ground surface profile is produced.

Detailed Description Paragraph Right (9):
FIG. 7 shows schematically a combine harvester on a field, which receives position signals from four ground-connected stationary basic stations for position determination of the reference point on the treatment device/cutter bar (b1, b2). The basic stations, whose position is very accurately measured in a terrestrial reference system, sends GPS signals as so-called pseudo satellites, in equivalence for satellites navigation with satellites which revolve around the earth in space. The signals of such pseudo satellites can be used as a correction factor for highly accurately operating GPS system. The combine harvester in accordance with this embodiment has satellite receiving antennas at both sides of the cutter bar.

Detailed Description Paragraph Right (10):
The embodiment of FIGS. 1-7 is illustrated for a combine harvester. For a person skilled in the art, with his professionally notorious knowledge it will be an easy task to transfer the proposed inventive device to another agricultural vehicle. For example, it is recommended to use a tractor with a plough as an agricultural vehicle, and to use frame points of the plough as reference points (b1, b2 . . .) whose working height is to be determined. With the inventive device the working depth of a plough can be controlled with simultaneous or alternative plotting, correction and/or with the help of an available historic data cadastre. Instead of a plough, naturally all other combinations of a tractor with known treatment devices are adjustable, such as drills, seeders, harrows, breakers, scooping devices, presses, cutting mechanisms, reversers, swathers, in which correspondingly suitable reference points (b1, b2) are

selected. In the same way the inventive device can be utilized with other agricultural vehicles, such as for example forage harvesters, sugar beet diggers, potato laying machines, and harvesters. In order to use the invention for different agricultural vehicles or exchangeable devices, such as for example various treatment devices on a tractor or alternating cutter bars or corn teeth on a combine harvester, the evaluating unit (AWE) in addition must be available through an input possibility, through which they are adjustable correspondingly to the determined reference points (b1, b2 . . .) when the reference points are not determinable automatically through a mounted device switch and/or with access to a memory.

Detailed Description Paragraph Right (12):
While the invention has been illustrated and described as embodied in agricultural vehicle with treatment device which is adjustable in its position and/or orientation relative to the vehicle, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

CLAIMS:

1. An agricultural vehicle, comprising a main vehicle; a treatment device arranged adjustably relative to said main vehicle with respect to at least one a position and an orientation of said treatment device; a satellite navigation receiving unit provided on a point of said main vehicle for determination of a position of said main vehicle; and an evaluating unit which determines from data of said satellite navigation receiving unit an absolute position of at least one reference point on said treatment device in connection with at least one sensor which allows to determine a relative position of said treatment device to said main vehicle.

2. An agricultural vehicle as defined in claim 1, wherein said satellite navigation receiving unit has a receiving antenna which is mounted on a reference point of said treatment device for determination of an absolute position of said at least one reference point.

3. An agricultural vehicle as defined in claim 1, wherein said satellite navigation receiving unit has a receiving antenna arranged on a point of said main vehicle for determination of a position of said at least one reference point; and further comprising a sensor determining a relative position of said treatment device to said main vehicle.

4. An agricultural vehicle as defined in claim 1; and further comprising a height sensor determining a relative height of said treatment device relative to said main vehicle.

5. An agricultural vehicle as defined in claim 1; and further comprising a transverse inclination sensor which determines a relative transverse inclination of said treatment device relative to said main vehicle.

6. An agricultural vehicle as defined in claim 1; and further comprising a sensor selected from the group consisting of a height sensor for determining a relative height of said treatment device relative to said main vehicle and a transverse inclination sensor for determining a relative transverse inclination of said treatment device relative to said main vehicle, said evaluating unit receiving a signal from said at least one sensor and transforming an absolute position of a point on the main vehicle determined by a satellite navigation to at least one reference point on said treatment device for determination of its absolute position.

7. An agricultural vehicle as defined in claim 1, wherein said evaluating unit is formed so that with use of said absolute position of said at least one reference point and a further point or a vector, it determines a characteristic reference line in a terrestrial reference system for an application of said treatment device.

8. An agricultural vehicle as defined in claim 7, wherein said evaluating unit determines said characteristic reference line which is provided by said reference point and a direction of a speed vector of said reference point.

9. An agricultural vehicle as defined in claim 7; and further comprising control electronic means of an automatic steering device arranged so that said reference line is further processed in said control electronic means as a steering signal.

10. An agricultural vehicle as defined in claim 7, wherein said evaluating unit is formed so that it determines a further characteristic reference line by said reference point and a further point or a vector.

11. An agricultural vehicle as defined in claim 10, wherein said evaluating unit determines said further reference line from said reference point and said further point or said vector transversely to a preferable traveling direction and therefore substantially perpendicular to said first mentioned reference line.

12. An agricultural vehicle as defined in claim 10, wherein said evaluating unit is formed so that said further reference line is determined by said first mentioned reference point and a second reference point.

13. An agricultural vehicle as defined in claim 10; and further comprising means for determining a transverse inclination of a ground surface from said further reference line.

14. An agricultural vehicle as defined in claim 10; and further comprising means for regulating a ground distance and a transverse inclination of said treatment device with the use of said further reference line.

15. An agricultural vehicle as defined in claim 12, wherein said evaluating unit determines said further reference line from said two reference points so that said two reference points in an immovable condition are located at a same distance over a ground surface and an inclination of said further characteristic line corresponds to an inclination of the ground surface.

16. An agricultural vehicle as defined in claim 15, wherein said both reference points are determined so that said inclination of said reference line corresponds to an inclination of the ground surface transversely to a preferable traveling direction.

17. An agricultural vehicle as defined in claim 1; and further comprising means for determining a distance from a ground surface of at least one of a reference point and a reference line.

18. An agricultural vehicle as defined in claim 1, wherein said evaluating unit is formed so that from a distance and a transverse inclination of said treatment device it determines a transverse inclination of a ground surface and further comprising means for continuously indicating said transverse inclination of said treatment device and said transverse inclination of said ground surface during position changes of said main vehicle and computing a three-dimensional terrain profile.

19. An agricultural vehicle as defined in claim 1; and further comprising means for determining a direction of a speed vector of said reference point received from data of said satellite navigation receiving unit, from two timely successive absolute positions of said reference point.

20. An agricultural vehicle as defined in claim 19; and further comprising means for determining a direction of a speed vector of said reference point from data of said satellite navigation receiving unit from sensor means for determining a speed.

21. An agricultural vehicle as defined in claim 1; and further comprising means for calculating a direction of a speed vector from a relative position and a relative speed of said reference point to a reference point on said main vehicle and an absolute position and a speed of said reference point.

22. An agricultural vehicle as defined in claim 1, wherein said satellite navigation receiving unit is provided with ground connected pseudo satellites.

23. An agricultural vehicle as defined in claim 1, wherein a reception of said satellite navigation receiving unit is supported by ground connected pseudo satellite.

24. An agricultural vehicle as defined in claim 1; and further comprising means for performing an additional dead reckoning navigation.

25. An agricultural vehicle as defined in claim 24, wherein said means for additional dead reckoning navigation include a gyro compass.

26. An agricultural vehicle as defined in claim 1; and further comprising means for storing a value selected from the group consisting of a drop, an inclination, and a transverse drop, joined with a position of said at least one reference point.

27. An agricultural vehicle as defined in claim 1, wherein said treatment device with use of values determined by said evaluating unit is controllable exclusively by determined position data in connection with a historic data cadastre.

28. An agricultural vehicle as defined in claim 1, wherein said values determined by said evaluating unit referred to said treatment device, are placed in a historic data cadastre, to control further treatments with same or other agricultural vehicles with controllable treatment devices on the basis of the historic data cadastre.

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L7: Entry 1 of 15 File: USPT May 21, 2002

DOCUMENT-IDENTIFIER: US 6389785 B1
TITLE: Contour scanning apparatus for agricultural machinery

Abstract Paragraph Left (1):
A device on a mobile agricultural machine for contactless scanning of contours extending over the ground, such as the contour of a swath of crop material. In this case there is used a laser distance measuring device consisting of a laser beam transmitting and receiving device which determines the distance from a contour point by measuring the running time of a laser scanning beam emitted and reflected at the contour point. The laser scanning beams are pivoted within a certain angular range stepwise or continuously in a scanning beam plane. In this case the laser distance measuring device is mounted with an orientation on the agricultural machinery such that the scanning beam plane is inclined to the ground at an acute angle forwards in the direction of travel. With the aid of an analyzer, the position of the contour point corresponding to each pivot angle, based upon the measured distance and the arrangement and orientation of the laser distance measuring device on the agricultural machine, can be determined.

Brief Summary Paragraph Right (2):
An apparatus generally of this kind is known from the article "Swath Scanning with Ultrasound" (periodical: Landtechnik 5-93, pages 266-268). The apparatus described there consists of a plurality of ultrasound sensors which are arranged on a fastening strip at a distance of 40 cm from each other and are directed vertically onto the ground. This fastening strip may, for example, be mounted on agricultural equipment such as a forager or an agricultural machine towing a baling press. By means of the ultrasound sensors the height a swath, for example of straw or green fodder, above the ground can be determined at certain points, allowing the contour of the swath over the ground to be scanned along a horizontal line. The device described therein, however, has at least a few significant drawbacks. That scanning device is relatively expensive because several ultrasound sensors are necessary for scanning. Furthermore there is insufficient distance between the ultrasound sensors and, as a result, the ultrasound sensors have a disturbing effect on each other due to inadequate focusing of the sound lobes. This limits the horizontal resolution or density of measuring points of contour scanning.

Brief Summary Paragraph Right (9):
A further object of this invention is to calculate an inclination offset.

Brief Summary Paragraph Right (10):
A further object of this invention is to use the inclination offset when calculating contour information.

Brief Summary Paragraph Right (11):
In accordance with the present invention, there is provided an agricultural machine having an apparatus for contactless scanning of contours extending over the ground comprising a laser distance measuring device, which has a laser beam transmitting and receiving device that determines the distance from a contour point by measuring the running time of the laser scanning beam emitted and reflected at the contour point. The laser scanning beams are pivotal within a certain angular range stepwise or steplessly in a scanning beam plane. In one embodiment the laser distance measuring device is mounted on the agricultural machine such that the scanning beam plane is inclined to the ground at an acute angle forwards in the direction of travel. With the

aid of an analyzer, for each pivot angle from the measured distance, the arrangement and orientation of the laser distance measuring device on the agricultural machine (mounting height, angle of inclination to ground) is determined, as well as the position of the contour point corresponding to the pivot angle (vertical and horizontal position above the ground).

Brief Summary Paragraph Right (12):
In accordance with another feature of the present invention there is provided a method of contour scanning during travel of an agricultural machine including the steps of providing a laser beam transmitting and receiving device; continually scanning the laser beam across the contour of the field in front of the machine; measuring the distance values from the laser beam; determine the contour of the field across the scanning width; and storing the contour information.

Brief Summary Paragraph Right (14):
Only one laser beam transmitting and receiving device is needed for the scanning device embodying the invention. Thus, this scanning device is considerably less expensive than the known ultrasound scanning device which requires several ultrasound sensors. The apparatus embodying the invention scans a contour in front of the agricultural machine at various points transverse to the direction of travel by pivoting the laser scanning beam. Thus the number of scanning points on a scanning line is substantially greater than with the ultrasound scanning device. Thus for example with a pivot angle range of .+-.45.degree. and pivoting of the laser scanning beam in 0.5.degree. steps, the result is 180 scanning points. Due to the low divergence of the laser scanning beam a relatively high resolution (density of scanning points) can be obtained, as the centers of adjacent scanning points lie close to each other without the scanning spots overlapping on the contour. Furthermore, unambiguous assignment of the point of reflection is possible.

Brief Summary Paragraph Right (16):
Scanning a significant distance ahead, such as is necessary for automatic steering along a scanned contour, can be achieved in a simple manner with the device embodying the invention. Thus, for example with a mounting height 380 cm. above the ground on an agricultural machine and an angle of inclination to the ground of 65.degree., a scanning distance in front of the agricultural machinery of approximately 8.15 m can be obtained. Due to the low divergence of the laser scanning beam, the scanning distance is not limited as in the case of ultrasound sensors. Contour scanning which may be achieved at relatively great distances cannot be achieved with the prior-art ultrasound scanning device. This would require a correspondingly long holding linkage in front of the agricultural machinery for receiving the fixing strip for the ultrasound sensors, which would cause the whole system to become completely impracticable.

Brief Summary Paragraph Right (18):
In a preferred embodiment the laser scanning beam is pivoted by means of a rotatable mirror or by means of a movable focusing device. Hence a relatively high number of scanning pivot paths per second and a high scanning frequency can be obtained, which is important particularly at higher traveling speeds. For example when using galvanometer motors for rotation of the rotary mirror, pivoting in a range of one millisecond is possible and, accordingly, a high scanning point density in the direction of travel of the agricultural machine can be obtained.

Brief Summary Paragraph Right (22):
Thus, it is provided that, during travel of the agricultural machine continuously along the path covered, the contour across the scanning width is determined and stored. By this method the contour of swaths of crop material to be picked can be scanned and recorded very accurately. With the aid of the scanned contour, an analyzer determines the cross-section of the scanned swath of crop material over the ground base line in each case. This swath cross-section determination is used to adjust the traveling speed of the agricultural machine, wherein regulation can be adjusted for example to constant or maximum pick-up of crop material. With a decreasing swath cross-section the traveling speed is increased, so that the crop material picked up per unit of time is constant. If crop material-specific density data are available, these can also be linked to the measured swath cross-section. This information, in conjunction with a measured swath distance traversed and volume calculation, makes it

possible to determine, on line, the crop material picked up during travel. Furthermore the swath-specific quantities determined in this way are in each case also used to adjust optimum working parameters of the harvesting machine.

Brief Summary Paragraph Right (25):
In conjunction with a real-time position finding system arranged on the agricultural machinery, such as a satellite navigation system or a global positional system (GPS), it is possible, over the whole area of use or over partial areas, to assign the scanned contours in each case to terrestrial coordinates (geographical length and width, if occasion arises height above NN--or Cartesian coordinates (x, y) referred to a point on the field). In this case, in addition to the swath-specific quantities, the distances between adjacent swaths are also determined and from them are generated surface area data or yield data. These are then stored for further use.

Brief Summary Paragraph Right (26):
Using a sensor on the agricultural machinery which determines the inclined positions of the agricultural machinery for example when used on a slope, or when traveling in hollows or over ground undulations, in conjunction with a GPS position finding system arranged on the agricultural machinery, by scanning the ground contour, taking into account the inclined positions of the agricultural machinery and position, a high-precision, three-dimensional terrain model of the agriculturally useful area can be produced. The inclined positions of the harvesting machine can also be used for easy correction of the scanning distance.

Brief Summary Paragraph Right (29):
Another advantageous use of the laser scanning device is the scanning of cultivation tracks. Such scanning during cultivation provides a means by which a agricultural machine can be steered automatically along a scanned track. This device is particularly suitable for scanning tracks or furrows such as those arising when plowing. Here the wide range of cover of the device proves to be particularly advantageous. In case of a reversal of the direction of cultivation, the laser scanning device does not have to be pivoted mechanically. Only the regulating signal has to be provided with an altered offset and fed to the automatic steering device. For this purpose for example sensors present on a plow can determine the position of the plow frame and convey it to the analyzer or steering regulator device. The offset can further be influenced manually or by an inclined position measuring means of the agricultural machinery.

Brief Summary Paragraph Right (30):
In another embodiment the laser scanning device allows a subsequent cultivation track only in the preselected identical direction of cultivation (e.g. general-purpose plow, cutter bars), can be mounted directly over the lane or cultivation edge on the cultivation implement or agricultural machine or harvesting machine. Conversion of the measured track position or addition of an offset can then be eliminated.

Drawing Description Paragraph Right (10):
FIG. 12 is side view of a portion of an agricultural machine's cab with a mounted laser scanning device.

Detailed Description Paragraph Right (1):
FIG. 1 shows an agricultural machine, i.e. a forager F, with a pick-up attachment PU picking up crop material located in a swath S. A laser distance measuring device LM is mounted at the top of the driver's cab C, i.e. a height of approximately 3.80 meters, and inclined at an angle of about 65.degree. to the ground. This setting of the laser distance measuring device LM provides a scanning distance of approximately 8.15 meters in front of the laser distance measuring device LM. The location of mounting on the agricultural machinery is in each case predetermined as a function of the structural peculiarities of the agricultural machinery and the specific purposes of use and should be selected as high as possible for optimum contour detection. To achieve high flexibility of adjustment, the laser distance measuring device LM is preferably mounted with adjustable height and inclination on the agricultural machinery.

Detailed Description Paragraph Right (3):
FIG. 3 charts the Pivot Angle a of the laser distance measuring device LM, the Driving Path Traversed, and the Height h. It shows a schematic three-dimensional view of the

swath SS contour scanned by the laser distance measuring device LM along the driving path traversed by the agricultural machine F. The distances between the contour lines in the direction of travel results from the scanning frequency or pivot time for the laser scanning beam LS, and the travel speed of the agricultural machine F.

Detailed Description Paragraph Right (6):
FIG. 6 is a block diagram of a microprocessor or analyzer 20 for calculating the scanned contour coordinates. The analyzer 20 receives input signals for the measured distance S from the contour point scanned at any given time, the pivot angle .alpha. at which each respective contour point is scanned, as well as the angle of inclination .phi. of the scanning beam plane to the vertical, and the height AH of mounting of the laser distance measuring device LM. From these data the analyzer 20 then calculates the contour coordinates. In advantageous embodiments the analyzer 20 receives further input signals such as the traveling speed from a speed sensor 22, GPS data from a position sensor 24, or information from an inclination sensor IN on the inclined position of the agricultural machine F. The analyzer 20 can be integrated in the laser distance measuring device LM or can be designed as one or more separate components. Preferably the analyzer 20 is connected to the agricultural machine's central control or vehicle bus system.

Detailed Description Paragraph Right (8):
In FIG. 7 are shown the geometrical ratios for the center point beam (.alpha.=0). The height h of the scanned contour point KP is determined from the measured distance So, the height of the laser distance measuring device's mounting AH and the angle of inclination .phi. as:

Detailed Description Paragraph Right (10):
FIG. 9 shows a graph with displayed distance values which have been corrected as in FIG. 8. The scanning beam LS used here has a range of approximately 50 m. At either point 1 or 2 the maximum scanning width is exceeded and the beam is no longer reflected. Measured values outside this pivot range are therefore invalid. A cosine path is calculated at points 1 and 2. At points 3 and 4 a more compact scanning width of the scanning beam was determined. At these points there are projections in the contour. They show in each case the position and the cross-section of a swath. The swath at point 3 lies slightly off center on the side towards the direction of travel of the harvesting machine. The swath center can be determined and, referred to the center point beam, used for automatic steering of agricultural machinery. At point 4 is shown another swath. By means of the angular positions of the two swath centers determined at any given time, the distance between the swaths can be determined and, in addition to the swath length, the swath cross-sectional area and the swath density, can be fed to a harvesting area determining means or yield mapping means. For a better calculation of the cross-sectional the ground inclination on the right and left sides from the swath can be use to determine the ground base line under the swath by a result of an interpolation of both side contours. According with this scanned cross-sectional area, the traveling speed can be adjusted. The volume of the picked-up crop material can also be determined in conjunction with the measured swath distance traversed. If more crop material information is available, such as the crop density, the swath volume can be calculated into a yield data signal. These can also be recorded for further use. With the laser scanner, it is possible to detect the distance between adjacent swaths. This space information allows one to determine the area of the swath (See, FIG. 9). One better solution is to use a GPS-Navigation system mounted on the harvester cab (See, FIG. 1, GPS) in connection with the yield over the whole area by storing the yield of the picked-up swath in connection with the GPS-position to create a yield map.

Detailed Description Paragraph Right (12):
The steps of the method of contour scanning include providing the laser beam transmitting and receiving device LM; continually scanning the laser beam LS across the contour of the field in front of the agricultural machine F; measuring the distance values from the laser beam LS; and determining the contour of the field across the scanning width. Advantageously the contour information is stored. Other advantageous steps include, either alone or in combination, determining a track to be followed by the agricultural machine F from the contour and from the sum of successive contours; utilizing said determined track for automatic steering of the agricultural machine F along the track; and generating a signal for the automatic steering and

adapting the signal by a manually controlled offset in such a way that a parallel shift between the measured track and the center point beam is accomplished. In one aspect the method includes the step of calculating the center of said track and using the same for further calculations. In some preferred uses the method is used to measure a swath, and includes determining, at any given time, the cross-section of the detected swath of crop material above the ground base line.

Detailed Description Paragraph Right (13):
FIG. 11 shows how one may use the laser rangefinder on the top of an agricultural machine's cab for detecting a track or a furrow FW forward in the travel direction of the agricultural machine F which in this instance is a farm tractor. The furrow or track can be detected in a full scanned contour by a jump in the measured range. The agricultural machine F will be automatically steered along the scanned track or furrow FW. A further new feature is the offset control device by means like a switch SW on the plow PL, which detect in which direction the plow is used. In FIG. 11 the furrow is on the left side to the agricultural machine F in travel direction. The offset like the transversal distance between the center beam CB in travel direction and the actual furrow FW is given by a part of the working-width PW of the plow left from the longitudinal axis of the agricultural machine F. Another new feature is present in the automatically altering offset in connection with one or two switches on the plow PL.

Detailed Description Paragraph Right (14):
FIG. 12 shows an inclination sensor IN in connection with the detecting device. This inclination sensor IN is also shown used on a combine in FIGS. 15 and 16. If the agricultural machine is working along a hill, the travel direction and the longitudinal axis of the machine are not in the same direction. So, the center beam CB, based for all further calculations, is not reflected from a point of the longitudinal axis of the agricultural machine and the calculation for the steering signal (crop boundary, swath), the cutting width (cutting load) or the offset (plowing) is not correct. With an inclination sensor IN this problem can be overcome in two ways. First, an inclination offset can be added to the calculation in according the inclination of the agricultural machine along a hill. Second, the whole device can be pivoted mechanically so that there is no deviation between the center beam direction and the travel direction of the machine.

Detailed Description Paragraph Right (15):
FIG. 12 shows a top of an agricultural machine's cab C with a mounted laser scanning device LM. On the top of the cab C there is also mounted a GPS-antenna GPS. Into the top of the driver's cab is one inclination sensor IN. In the middle of the roof in the cab, in front of the windshield, is a hole. In this hole the laser scanning device LM is fixed. The device LM can be adjusted by hands in the height and also the acute angle of the laser scanning device LM to the ground. FIGS. 13 and 14 show a same device LM as the figure on top of this side, but with an automatic adjusting device M which pivots the device around the axle AX. This device M can be use in connection with the inclination sensor IN or for pivoting the whole device with a fixed laser beam for scanning over a full contour or for both.

Detailed Description Paragraph Right (16):
Features have been described in connection with a laser distance measuring device mounted at the roof of the agricultural machine cab C. This is only the preferred embodiment for the described applications. The laser distance measuring device may also be mounted on a lower position in front of or behind the windshield. It may also be spaced transversal from the longitudinal axis of the agricultural machine.

Detailed Description Paragraph Left (2):
If for example a scanning distance of .DELTA.X=11.1 cm is predetermined by a traveling speed of v=10 km/h and a pivot angle frequency of 25 Hz (scanning frequency), at an angle of inclination of .phi.=65.degree., the result is a maximum scannable difference height of .DELTA.h=5.2 cm. Such a value is sufficient for the applications of the method.

Detailed Description Paragraph Type 1 (2):
.phi.: the angle of inclination of the scanning beam plane to the vertical plane;

CLAIMS:

1. In an agricultural machine, an apparatus for contactless scanning of contours extending over ground; the improvement comprising:

a laser distance measuring device including a laser beam transmitting and receiving device which determines the distance from at least one contour point by measuring a running time of a laser scanning beam emitted and reflected at the at least one contour point;

the laser scanning beam being pivotal by a pivoting mechanism within an acute angular range stepwise in a scanning beam plane;

the laser distance measuring device being mounted on the agricultural machine such that the scanning beam plane is inclined to the ground at an acute angle forward in a direction of travel; and

a processor operatively connected to the laser measuring device for receiving input for a measured distance, input for an arrangement and orientation of the laser distance measuring device, including a mounting height and angle of inclination to the ground, and the processor being operative for determining a position of the at least one contour point as an output.

2. The apparatus according to claim 1, wherein the laser distance measuring device is adjustably mounted for height on the agricultural machine by an adjusting mechanism.

3. The apparatus according to claim 1, including an inclination sensor on the agricultural machine for determining inclined positions of the agricultural machinery and sending a signal to the processor for use in determining the at least one contour point.

6. The apparatus according to claim 3, further including an automatic adjusting device attached to the laser distance measuring device for pivoting the laser distance measuring device in response to an input signal from the inclination sensor.

9. A method of contour scanning during travel of an agricultural machine on ground including the steps of:

determining a distance from at least one contour point by measuring a running time of a laser scanning beam emitted and reflected at the at least one contour point with a laser beam measuring device that includes a laser beam transmitting and receiving device mounted on the agricultural machine such that the scanning beam plane is inclined to the ground at an acute angle forward in a direction of travel;

pivoting the laser scanning beam by a pivoting mechanism within an acute angular range stepwise in a scanning beam plane; and

receiving input for a measured distance including an arrangement and orientation of the laser distance measuring device, including a mounting height and angle of inclination to the ground, and determining the at least one contour point as an output with a processor that is operatively connected to the laser beam measuring device.

10. The method according to claim 9, including a step of determining a track to be followed by the agricultural machine with the processor from the at least one contour point.

11. The method according to claim 10, including the step of utilizing the determined track for automatic steering of the agricultural machine along the determined track with an automatic steering device.

14. The method according to claim 13, wherein the step of adapting the signal includes determining an inclined position of the agricultural machine and adapting the signal, which is dependent upon the determined inclined position by an offset from an offset control device.

15. The method according to claim 13, wherein the step of adapting the signal includes

determining a working direction of the agricultural machine and adapting the signal, which is dependent upon the working direction by an offset from an offset control device.

16. The method according to claim 10, wherein the track is a furrow and the agricultural machine is steered along the furrow.

19. A method according to claim 18, including the steps of determining a scanning frequency of a laser distance measuring device; sensing a traveling speed of the agricultural machine; and using the cross-section of the swath of crop material in conjunction with the scanning frequency and the traveling speed to determine a volume of the cross-section of the swath of crop material.

22. The method according to claim 20, including determining a quantity of yield of harvested crops and using the quantity of yield of harvested crops to adjust working parameters of the agricultural machine with the processor.

23. The method according to claim 20, wherein a quantity of yield of harvested crops is used to adjust a traveling speed of the agricultural machine with the processor.

24. The method according to claim 9, wherein over at least a portion of the field, the at least one contour point is assigned terrestrial coordinates by a position finding system located on the agricultural machinery and the terrestrial coordinates are stored for further use.

26. The method according to claim 9, further including detecting a direction in which a working device on the agricultural machine is used with an offset control device.

28. The method according to claim 9, further including a step of calculating an inclination offset with the processor.

29. The method according to claim 28, further including a step of using an inclination sensor to provide input to the processor to calculate the inclination offset.

30. The method according to claim 26, further including a step of factoring an inclination offset when determining the at least one contour point with the processor.

32. The method according to claim 9, including the steps of: scanning with the laser beam by a pivoting mechanism across a path of the agricultural machine; and detecting obstacles in the path of the agricultural machine.

34. The method according to claim 9, further including the step of utilizing the at least one contour point to regulate a height of a harvesting mechanism with a height adjusting device associated with the agricultural machine.

35. The method according to claim 9, further including the steps of: setting a threshold value for an increase in height of the at least one contour point in a direction of travel in front of the agricultural machine; and generating a signal if the threshold value is exceeded.

36. The method according to claim 9, further including the steps of: determining a mean height of a contour of the crops based the at least one contour point; and

using the mean height of the contour of the crops to regulate a height of a reel associated with the agricultural machine.

38. In an agricultural machine, an apparatus for contactless scanning of contours extending over the ground; the improvement comprising:

a laser distance measuring device including a laser beam transmitting and receiving device which determines the distance from at least one contour point by measuring a running time of a laser scanning beam emitted and reflected at the at least one contour point;

the laser scanning beam being pivotal by a pivoting mechanism within an acute angular range stepwise in a scanning beam plane;

the laser distance measuring device being mounted on the agricultural machine such that the scanning beam plane is inclined to the ground at an acute angle forward in a direction of travel; and

a processor for receiving an input for a measured distance, input for the arrangement and orientation of the laser distance measuring device, including a mounting height and angle of inclination to the ground, and the processor being operative for determining a position of the at least one contour point as an output; and

an inclination sensor mounted on the agricultural machine for determining inclined positions of the agricultural machinery and sending an input to the processor for use in determining the at least one contour point.

39. The apparatus according to claim 38, wherein the agricultural machine includes a cab and a roof on top of the cab and wherein the laser distance measuring device is mounted at the roof of the cab.